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Инновационные спилловер-эффекты информационно-коммуникационных технологий в высшем образовании

Современное развитие образования происходит в условиях экспоненциального роста создания и использования информационно-коммуникационных технологий и интенсификации инновационной деятельности. Цель исследования – продемонстрировать вертикальные и межотраслевые спилловер-эффекты распространения технологических инноваций и информационно-коммуникационных технологий и раскрыть их роль в развитии сферы высшего образования и рынка образовательных услуг.

С использованием методов эмпирического, сравнительного, статистического и картографического анализа по регионам России за 2013-2018 гг. были проанализированы показатели динамики рынков дистанционного и online образования, количества обучающихся, числа вузов, занятых подготовкой кадров для IT-сферы, поданных заявок на государственную регистрацию программ для ЭВМ и баз данных, комплексно характеризующие процессы распространения инновационных спилловеров.

Одним из ключевых факторов структурных сдвигов в высшем образовании определены технологические инновации, результат воздействия которых заключается в появлении новых методов и направлений образования, развитии дистанционного обучения, формировании электронной информационно-образовательной среды, технологических платформ и образовательных ресурсов как проявления спилловер-эффекта.

Установлено, что технологические инновации порождают значимые спилловер-эффекты, влияют на структурные пропорции национальных экономик, приводят к трансформации рынка труда и изменяют структуру спроса и предложения на рынке образовательных услуг, обуславливая потребности в специалистах с области IT и определяя характер будущих рабочих мест, расширяют число сегментов и увеличивают ёмкость сферы образования и ее вклад в региональный экономический рост. Учет влияния проявлений спилловер-эффектов необходим при планировании и прогнозировании качественных и количественных параметров развития сферы высшего образования и рынка образовательных услуг.

Ключевые слова: высшее образование, информационно-коммуникационные технологии, инновации, спилловер-эффекты, дистанционное обучение

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Innovation spillover effects of information and communications technology in higher education

The modern education is developing under conditions of exponential growth in the creation and use of information and communication technologies and the intensification of innovation. The purpose of the research is to demonstrate the vertical and intersectoral spillover effects of the technological innovations and information and communication technologies spread and highlight their role in the development of higher education and the market of educational services.

Using the methods of empirical, comparative, statistical and cartographic analysis in regions of Russia for 2013-2018, the indicators of the dynamics of the distance and online education, the number of students and universities, involved in the training for the IT sphere, the applications for state registration of computer programs and databases, that comprehensively characterize the distribution processes of innovative spillovers, were analyzed.

One of the key factors of structural changes in higher education is technological innovation, the result of which is the emergence of new methods and directions of education, the development of distance learning, the formation of an electronic information and educational environment, technology platforms and resources as manifestations of the spillover effect.

It has been established that technological innovations generate significant spillover effects, affect structural proportions and lead to the transformation of the labour market, change the structure of supply and demand in the educational services market, determining the requirements for IT specialists and determining the nature of future jobs, expand the number of segments and increase the capacity of the education sector and its contribution to regional economic growth. The influence of manifestations of spillover effects is necessary to account when planning and forecasting the qualitative and quantitative parameters of the development of higher education and the market of educational services.

Key words: higher education, information and communication technologies, innovations, spillover effects, distance learning

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Introduction

Modern development of higher education is greatly influenced by the exponential growth in creation and application of information and communication technologies (ICT), intensification of innovational activities and influx of technological, organizational and marketing innovations. Nowadays, digital economy is growing 2.5 times faster than the global GDP. The return on investments (ROI) in digital technologies in a long-term perspective is 6.7 times higher than ROI in non-digital assets [1]. This enables to predict a significant growth of ICT in the short-term perspective and makes it necessary to consider these tendencies during the educational process as well as during the analysis and planning of higher education development.

Digitalization effects: 5G, cloud technologies, big data, the Internet of things, artificial intelligence and ICT are becoming widespread in all educational spheres.

Apart from direct effects, innovations also provide an implicit influence that is not related to a specific innovative technology. There is a gradient growth of spillover effects — indirect effects of ICT spreading and their impact on participants that are not involved in the interaction [2].

Scientific literature studies innovation spillover effects as effects of innovation activities that led to other innovations. Spillover effects occur when some activities affect subjects that are not directly involved in the interaction [3]. A spillover is a interdisciplinary notion. Economics analyzes various forms of spillover effects as a part of externality theory [4-6]. Traditionally, foreign researchers estimate spatial spillover effects between university research and regional high-tech innovations, pointing out that the transfer of university technologies has a positive influence on regional development [7-9].

Modern Russian researchers who study spillover effects in educational processes focus on changes in higher education institutions and their effect on regional development, in particular regional innovational development [10]. For example, the number of universities and other higher education institutions correlates with such indicators as per capita income dynamics and the share of investments in GDP in main capital. Special attention is paid to knowledge spillover effect — this phenomenon occurs when the information collected and applied for performing a certain activity eventually creates opportunities to apply this knowledge in other areas. The spillover acts as a catalyst for development of new ideas and new ways of their application. University research provides spillover effects on regional innovation systems and may facilitate indirect transfer of knowledge [11]. Furthermore, higher education institutions provide access to knowledge, this is why theorists study the ways academic knowledge is transferred to the public sector and innovations are transferred for integrating education, science and production [12; 13] and the role institutions and social capital play in higher education reforms [14].

Studies of spillover effects in pedagogy analyze specifics of innovational informational environment, innovative activity and innovative staff, distance learning technology as a way of obtaining higher education [15; 16].

However, scientific literature does not provide sufficient coverage of interdisciplinary innovation spillover effects in education that significantly influence the development of education and educational services market as a whole and for each territory in particular. This subject is relevant and significant for predicting qualitative and quantitative trends

of higher education development and educational services market changes as well as for conducting research innovational regional development.

This work analyses the influence of ICT innovations on higher education and educational services market. The main objective of this article is to highlight the role ICT and technological innovations play in higher education development and to demonstrate interdisciplinary spillover effects of ICT spreading. The scientific novelty of this research is in developing theoretical aspects and methods for assessing representation of ICT innovation spillover effects in higher education.

Materials and methods

The methodology of this research is based on the analysis of representation and identification of ICT innovation spillover effects on the material of higher education institutions in 83 Russian regions.

As the objects of the research we have analyzed the indicators of distance and online education market dynamics, the number of personal computers used for educational purposes, the student body and the number of institutions in Russian regions preparing IT specialists, the number of applications submitted for state registration of computing programs, databases, and integrated circuits layouts that characterize innovation spillover processes.

The informational basis for the research was provided by the Central database of the Russian Federal State Statistics Service (Rosstat), informational and analytical materials summarizing the monitoring of higher education institutions efficiency by the Ministry of Education and Science and the Russian Federal Service for Intellectual Property (Rospatent) for 2013-2018. The research used methods of comparative, economic, cartographic, economic and statistical analyses.

Discussion

Current technological and innovational changes apply to various areas including higher instructions. ICT, information products and technologies have become an integral part of all aspects of human activities. It is hardly possible to imagine a situation where no multifunctional gadgets with lots of useful apps or computers with assisting software are available. These new trends cause structural shifts in higher education.

Our analysis enables to reveal the most significant representations of ICT spillover effects. One of the examples of ICT spillover effects is the invention of a computer and consequent transfer of technologies that initiated new forms of education. In 1883 Charles Babbage outlined the main principles of computer work. His ideas were put to life in late 19th century when in 1896 Herman Hollerith founded the company later known as the Computing-Tabulating-Recording Company. This enterprise eventually evolved into IBM Company that greatly contributed to the development of computing equipment. In 1941 Howard Aiken designed Mark I, the first computer that became the basic innovation in computer science and information technology. Later improvements made the computer more efficient and user-friendly. The flow of improving innovations gradually expanded. Everyday application of computers by a large number of users resulted in the appearance of new educational services consumers, ways to exchange data, interactions between

educational process participants and educational market segments, i.e. distance and online education.

Distance education originated in the 19th century when British teacher Isaac Pitman introduced the notion of correspondence courses. Until the early 20th century distance learning was conducted by mail. The age of personal computers that started in the late 1980s made the first step towards the automation of education.

The development of distance and online education is the significant result of innovation spillover effect of ICT application in education.

In the USSR, distance education forms appeared in the early 1960s; however, due to economic situation in Russia and lack of wide access to the Internet, this educational format did not become commonly spread. The situation changed only when the Internet became widespread in Russia, thus launching a rapid development of electronic education.

In modern Russia the main distance education drivers are higher education institutions that are actively applying ICT and distance technologies for preparing specialists of various disciplines.

In 2018, the volume of Russian distance education market reached 29 bln rubles demonstrating a significant increase in the recent decade. According to the experts, by 2021 the growth rate of this market will achieve 17-20% annually. By 2021 the market volume is expected to reach 53.5 bln rubles. The share of online education in the educational structure will comprise 2.6% in 2021 [17]. The market will provide more offers, programs and tools. The increasing supply causes the market structuring. The most efficient companies in the industry are developers of digital education solutions based on game mechanics and simulation of real-life processes.

Intensive growth of ICT caused by development of the Internet technologies coupled by active implementation of distance education in Russian higher education institutions soon may lead to the target audience increase up to 20-30 mln students. These tendencies must be note while planning the main parameters of higher education development.

Results

Statistical data show that in 2010-2017 the average usage of personal computers increased in Russia by 29%. This also influenced the appearance of interdisciplinary innovation spillover effects.

The dynamics of the number of personal computers used for educational purposes is shown on Fig. 1-2.

However, educational services market dynamics cannot be characterized only by quantitative changes in supply and demand. Scientific progress initiated new forms of activities and employment. Higher education institutions are providing new fields of study. The labor market is changing causing shifts in supply and demand of the educational services market.

An upsurge in scope and share of modern ICT in economy and increased ICT application cause significant spillover effects and affect structural proportions of national economies shaping future workplaces and increasing the demand for IT specialists. These spillover effects also lead to appearance of new educational segments and new professions, especially in the ICT industry: "IT specialists, tech guys" (programmers, webmasters, etc.).

The analysis of the number of students studying these disciplines in Russian federal districts and region enables to estimate the new segment on the educational services market and the scope of the innovation spillover effect (Fig. 3).

Figure 1 Dynamics of the number of PCs used for educational purposes per 1000 students Rosstat, 2017[18]

Figure 2 The increase in the number of PCs used for educational purposes per 1000 students by federal district Rosstat, 2017, [18]

Within five years, from 2013 to 2017, the average growth of students getting bachelor's degrees in IT disciplines comprised 25%. Meanwhile, the analysis of data provided by Fig. 4 reveals unevenness of innovation spillover effects in different regions. Spatial distribution of an innovation spillover effect, its scope, representation type, power and velocity are determined by differences in regional industry and reproduction economic structures as well as by specifics of regional higher education. This causes uneven regional perception of innovation spillovers effects.

Fig. 4 demonstrates that most students learning IT disciplines study in the regions of the Central Federal District, predominantly in Moscow universities (48% in 2013 and 53% in 2017), while the number of higher education institutions almost halved. Statistical data for the student body reveal positive dynamics. The number of students learning ICT-related disciplines increased by more than 20% in most regions, with the Volga Federal District demonstrating the biggest growth.

Figure 3 Dynamics of the student body and the number of institutions preparing IT specialists in 2013-2017 by federal district [19]

Figure 4 Dynamics of the student body and the number of institutions preparing IT specialists in 2013-2017 by region [19]

All regions of the North Caucasus Federal District demonstrate a tendency for reduction, in particular in the number of higher education institutions preparing IT specialists. This can be explained by the fact that education institutions are restructuring or merging. Cities that prepare most IT specialists are Moscow, St. Petersburg and Novosibirsk due to high concentration of universities that according to 2016 data are highly ranked among institutions providing ICT training (Fig. 5).

Figure 5 Top 10 universities preparing IT specialists, 2017 [20]

Figure 6 Regional changes in the IT student body in comparison between 2017 and 2013, %

We also analyzed patent activities. Figures 7 and 8 show the dynamics in submitting application for state registering of ICT-related patents in 2009-2016 by federal district.

Figure 7 The number of applications for state registering of programs and databases [21; 22]

As charts on Figure 4 show, the total number of ICT patents submitted for state registering has increased during the analyzed period. All federal districts have positive dynamics. Meanwhile, Figures 4 and 5 demonstrate most patents are submitted in the Central Federal District regions (that also have the biggest share of patents), followed by the Volga Federal District regions.

Figure 8 Information on applications for state registering of programs and databases submitted in 2018 by federal district, % [21; 22]

In 2010-2016, the number of ICT patents submitted for state registering increased by 77.9% in the Central Federal District, 77.4% in the Volga Federal District, 56.2% in the

Southern Federal District, 76.6% in the North Caucasus Federal District, 77.8% in the Ural Federal District, 87.3% in the Siberian Federal District, while in the Northwestern and Far Eastern Federal Districts their number doubled. In 2018, the share of patents had no significant changes in any federal district compared to 2017.

Comparison of the statistical data on the number of ICT patents submitted for state registering, the student body and the number of higher education institutions preparing IT specialists reveals that regions preparing most IT professionals also demonstrate high patent activity, which is a sign of interdisciplinary spillover effects.

Application of technological innovations requires personnel changes and involvement of highly qualified labor. Russian higher education institutions have already adopted their educational programs for preparing IT specialists. In 2015, professional standards were added to the Labor Code of the Russian Federation that regulate the education level of IT personnel. The professional standards set the requirements that do not allow a person with a law or technical engineering diploma work as a programming engineer even if this person has sufficient experience in programming.

New activities, professions and competences are emerging nowadays, which have not been yet take into consideration by higher education institutions or education supervising agencies. Russian scientific and educational community considers various types of future IT professions as one of the fastest-growing segments of the educational services market (Table).

Table

Current and potential fields of study of ICT specialists [23]

Existing fields of study of ICT specialists now	Prospective IT professions after 2020
Applied Mathematics and Information Science Fundamental Information Science and Information Technologies Mathematical Provision and Administration of Information Systems Programming in Computing Systems Information Science and Computing Equipment Information Systems and Technologies Applied Information Science Software Engineering Information Security Information Security of Automated Systems Business Information Science	Information security supervisor Personal profile security consultant Cyber researcher IT auditor Big Data models developer Digital linguist IT evangelist Cyberspace lawyer Interface designer Information systems architect Neural interface designer Smart environment cybertechnician

Modern economy needs graduates that are capable of creative, out-of-the-box thinking, actively participate in innovation processes and have competence to complete occupational and research objectives. Lack of qualified personnel in basic branches of economy in Russian regions remains a serious problem that creates obstacles for economic growth and shift to more progressive technologies. To upgrade Russian economy and provide its competitiveness, it is obligatory to create the education system that meets the demands of economy and potential labor market.

Nowadays we have to answer whether the education system is ready to respond to these challenges and offer specialists like VR and VR devices architects and designers, biohackers, neural interface supervisors etc. to the labor market and whether Russian higher education system is capable of flexible interaction with actors and stakeholders and adequate planning of its development directions. There is an evident time gap between adaptation of digital technologies and preparation of specialist for their professional and efficient application. Most Russian regions demonstrate structural disproportions and incongruence of the labor market demand for IT certain specialists and programs provided by higher education institutions.

Conclusion

Thus, innovation spillover effects of ICT development and application led to structural and institutional changes in education as well as to radical paradigm shift in pedagogical science. Spreading of basic innovations enabled to develop information and communication technologies, shape new activities, professions and educational services market segments, which expansion leads to an increase in patent activities, improving innovations and innovative products. Innovation in one area resulted in innovations in another one. This can be characterized as an interdisciplinary vertical innovation spillover effect.

Innovations spillover effects resulting from ICT application include new bachelor and master programs preparing qualified specialists for informational segment of economy: new informational education environment has formed that consists of informational resources and ICT. Another effect of innovation spillover effects is appearance of new educational tools and methods. Computerization enabled to introduce new teaching methods, diversify educational processes and make it more efficient and practice-focused. Even curricula of education institutions nowadays list ICT used in the teaching process. The structure of education market and education programs has changed and new forms of study appeared, such as distance education, online education, technological educational platforms and resources.

At the same time territorial distribution of knowledge and innovations is uneven. Differentiation of Russian regions is demonstrated in this research by spatial distribution of innovation spillover effects and their unequal representation in donor and recipient regions. High concentration of all necessary resources – labor, financial and informational – in central regions, most of which are donor regions, accelerates innovation diffusion; besides, innovation spillover is accompanied by innovation transfer. As a result of these factors, the volume of ICT application is increasing consequently stimulating new types of spillover effects, thus expanding the number of affected segments and increasing the application scope of education and its contribution to regional economic growth.

Modern conditions require an education development and functioning strategy that is aimed at improving its efficiency, increasing employment rate of graduates, maintaining labor market balance and providing qualified workforce for the economy.

The analysis that we conducted proves the necessity and importance of studying innovation ICT spillover effects in education. The main challenges are the complexity of spillover effects that involve multiple aspects and the need for efficient measures and management decisions while planning innovation policy of regional higher education.

Quantitative and qualitative efficiency growth of higher education and improved professional training of future specialists can be achieved by the following incentives: education institutions should eliminate inertia and take a proactive stance, adopt best teaching practices, develop distance and online education, actively implement ICT and consider actual demands of regional labor markets.

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REFERENCES

1. Digital Spillover. Measuring the true impact of the Digital Economy. *A report by Huawei and Oxford Economics*. Published: September 5, 2017. Available at: <https://www.huawei.com/en/press-events/annual-report/2018> (accessed 10 August 2019)
2. Ivanova M. V. Spillover effects in the Russian economy as a factor in the development of investment attractiveness of regions. *Scientific journal*, 2017, no. 10 (23), pp. 28-31.
3. Feodorova E. A., Korkmazova B. K., Muratov M. A. Spillover effects in the Russian economy: regional specifics. *Regional Economy*, 2016, no 1(12), pp. 139-149.
4. Pigou A. S. *Economic theory of welfare*. Moscow, Progress Publ., 1985.
5. Melikhov V. Yu. Forms of externalities (external effects from education). *Bulletin of KSU named after N.A. Nekrasov*, 2006, no. 6, pp. 216-230.
6. Sosodov G. A. Externalities of higher education in the context of strengthening the role of higher education in the economy. *Bulletin of TSU*, 2010, no. 4 (84), pp. 29-36.
7. Griliches Z. Issues in assessing the contribution of R&D to productivity growth. *Bell Journal of Economics*, 1979, no. 10(1), pp. 92-116.
8. Jaffe A. Real effects of academic research. *American Economic Review*, 1989, no. 79, pp. 957-970.
9. Luc Anselin, Attila Varga, Zoltan Acs. Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics*, 1997, no. 42, p. 422-448.
10. Firsova A. A., Chernyshova G. Yu. Mathematical Models for Evaluation of the Higher Education System Functions with DEA Approach. *Izv. Saratov Univ. (N. S.), Ser. Math. Mech. Inform.*, 2019, vol. 19, iss. 3, pp. 351-362. DOI: <https://doi.org/10.18500/1816-9791-2019-19-3-351-362>
11. Firsova A.A., Narhova A.A. International Approaches to Assessment of University for Regional Development. *Izv. Saratov Univ. (N.S.), Ser. Economics. Management. Law*, 2014, 14 (2-1), 289-294.
12. Chelnokova O. Yu., Gritsak L. E. Development of the integration of education, science and production in the form of technology transfer in the modern phase of the innovation cycle of the Russian Federation. *Izv. Saratov Univ. (N.S.), Ser. Economics. Management. Law*, 2013, vol. 13 (1), pp. 8-14.
13. Izotov M. A. The process of transfer of innovations in integrated structures of higher professional education. *Vestnik DSTU*, 2012, no. 6 (67), pp. 153-160.
14. Volchik V. V., Krivosheeva-Medyantseva D. D. Reforms in higher education: the role of institutions and social capital. *Journal of Institutional Studies*, 2016, vol. 8, no. 2, pp. 87-104. DOI: 10.17835 / 2076-6297.2016.8.2.087-104
15. Seregina E. A. The Technology of Distance Learning as a Way of Obtaining Higher Education in Russia. *Perspectives of Science & Education*, 2018, no. 2 (32), pp. 25-29.
16. Zagraikina I.N., Ostapenko R. I. Innovative activity and innovative staff in the modern economy. *Perspectives of Science & Education*, 2017, no. 2 (26), pp. 68-71.
17. NeoAnalytics. The Russian distance learning market: results of 2018, forecast up to 2021. Available at: <https://marketing.rbc.ru/articles/10886/> (accessed 10 August 2019)
18. Federal State Statistics Service (Rosstat). Available at: http://www.gks.ru/free_doc/doc_2017/rusfig/rus17.pdf (accessed 10 August 2019)
19. Information and analytical materials on the results of monitoring the effectiveness of the activities of educational organizations of higher education. Available at: <http://indicators.miccedu.ru/monitoring/?m=vpo> (accessed 10 August 2019)
20. Rating of Russian universities graduating IT specialists. Available at: <https://fondatom.ru/rejting-rossijskih-vuzov-vypuskayushhih-spetsialistov-v-sfere-it/> (accessed 10 August 2019)
21. Report on the activities of Rospatent for 2017. Moscow. Text, Rospatent. 2018.
22. Report on the activities of Rospatent for 2018. Moscow. Text, Rospatent. 2019.
23. Atlas of new professions. Agency for Strategic Initiatives, Moscow School of Management Skolkovo, 2018. Available at: <http://atlas100.ru/catalog/?otrasl=all> (accessed 10 August 2019)

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